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Measurements of alpha and beta radiation from uncontaminated surfaces of common building materials using the RadEye SX with Ludlum 43-93 Probe

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Introduction

Federal regulation requires the measurement of radioactivity located in or on potentially-contaminated items or materials prior to public release. Surface radioactivity must be at or below radioactivity limits that are protective of the public. These limits are low enough that contributions to radioactive emissions from naturally occurring radioactive materials (NORM) in the building materials must be considered. In uncontaminated materials, measurements commonly reflect NORM content inside construction materials in addition to radon decay products that have collected on surfaces. Therefore, it is important to quantify typical background NORM count rates to accurately determine the fraction of radioactivity added to building materials by radiological operations.

In Department of Energy facilities, and specifically Los Alamos National Laboratory (LANL), there are numerous buildings scheduled for Decontamination and Decommissioning (D&D). While many of these buildings never hosted radiological operations, some did and have the potential for residual radioactive contamination on the building surfaces. Numerous regulations and requirements protect public safety by preventing excessive exposure to potentially contaminated materials (e.g., 10 CFR 835, DOE 458.1,). Specifically, Department of Energy Order 458.1, *Radiation Protection of the Public and the Environment* (DOE 2013), provides guidance for evaluating material releases and establishes a dose limit of 1 mrem/yr (10 µSv/y) for the release of personal property to the public. This order also affirms the surface contamination limits found in the predecessor order DOE Order 5400.5 (DOE 1990) as authorized limits for public release of materials. Additionally, the American National Standards Institute (ANSI) and the Health Physics Society have jointly produced guidance for material release that relies upon a dose limit to the public of 1 mrem/y (10 µSv/y) from a material's radionuclide content (ANSI N. 13.12 (2013)).

In addition to the federal requirements in DOE Orders, the state of New Mexico requires that waste materials sent to commercial landfills contain no measureable LANL-derived radioactive materials. Thus, debris can be buried in commercial landfills only if measurements indicate radioactivity levels are indistinguishable from background. If any anthropogenic contamination is detected, the debris must be buried as radioactive waste. Thus, measuring the NORM contribution to the radioactivity measurements of materials to be released is critical.

LA-UR-15-28370, *Measurements of Alpha and Beta Radiation from Uncontaminated Surfaces of Common Building Materials*, provides an in depth analysis of NORM in building materials and their impact on determining whether waste material contains no measureable LANL-derived radioactive material.

Problem Statement

LANL recently added a new instrument configuration, Thermo RadEye SX with Ludlum 43-93 Dual Scintillator. In 2015, measurements, using the Eberline E-600 with SHP-380AB scintillator were made on uncontaminated surfaces of building materials at a variety of locations to characterize background levels of alpha and beta activity. The building materials selected included painted and bare concrete (poured and cinderblock), metal (painted, rusted, and galvanized), wallboard, stucco, tile, wood (bare and painted), ceiling tile, and carpet (Whicker et al., 2015). The Eberline SHP-380AB has slightly different characteristics than the Ludlum 43-93 (e.g., different probe sizes, counting efficiency across the probe surface, and data processing). Therefore, it was determined that measurements of uncontaminated building materials should be taken with the Ludlum 43-93.

The purpose of this study was to measure the levels of surface activity found on common building materials that are uncontaminated. The instrumentation and techniques used are the same as those used in D&D of LANL buildings and the same methodology as Whicker et al. (2015). These measurements can then be used to statistically evaluate whether gross or net positive measurements on these building materials are indicative of contamination from nuclear operations in the facility, or alternatively, if the measurements reflect NORM and are indistinguishable from background.

Table 1: SHP380AB manufacturer's technical data

Feature	Description
Application	Alpha/beta surface contamination surveys
Detector	5 mg/cm^2 ZnS(Ag) coated onto a 0.3 mm-thick plastic scintillator
Window thickness	0.87 mg/cm^2 metalized film
Window dimensions	6.9 cm x 14.5 cm (100.1 cm^2)
Weight	456 g (1.0 lbs.)

Table 2: Ludlum 43-93 manufacturer's technical data

Feature	Application
Application	Alpha/beta surface contamination surveys
Detector	5 mg/cm^2 ZnS(Ag) coated onto a 0.25 mm-thick plastic scintillator
Window thickness	1.2 mg/cm^2 metalized film
Window dimensions	7 cm × 14.7 cm (102.9 cm^2)
Weight	606 g (1.33 lbs.)

Table 3: SHP380AB measurement summary

Isotope	Relative efficiency	Beta Correction Factor
^{36}Cl	1.0	1.0
$^{90}Sr/^{90}Y$	1.0	1.0
^{137}Cs	0.8	1.25
^{99}Tc	0.5	2.0
^{14}C	≈ 0.167	≈ 6

Table 4: Ludlum 43-93 measurement summary

Isotope	Relative efficiency	Beta Correction Factor
^{36}Cl	1.0	1.0
$^{90}Sr/^{90}Y$	1.0	1.0
^{137}Cs	0.8	1.25
^{99}Tc	0.5	2.0
^{14}C	≈ 0.167	≈ 6

Regulatory Requirements for Release of Personal Property

DOE Order 458.1 requires that potentially contaminated personal property released to the public must be monitored and that any residual radioactive contamination must not contribute more than 1-mrem/yr. Additionally, DOE requires that the potential public dose from the release of the property meets As Low As Reasonably Achievable (ALARA) guidance. Buildings with potential for residual surface contamination must be carefully and systematically surveyed for contamination (MARSSIM 2002; MARSAME 2009). This approach assures statistically representative sampling of the items and materials. The results of these measurements are compared to release limits specific to the disposition pathway [e.g., indistinguishable from background for commercial landfills, or less than the pre-approved authorized levels for surface contamination found in DOE Order 5400.5 (DOE 1990) and reaffirmed in DOE Order 458.1 (2013) Section 4.k.(6)(f)b]. Table 5 provides the surface and volume contamination values from ANSI 13.12 (2013) that can equate to the 1 mrem/yr limit in DOE Order 458.1.

Table 5. Surface and volume screening levels(1) for the various groups of radionuclides. Limits based on a 1-mrem/yr public dose.

Radionuclide Groups and radionuclides common to LANL	Surface contamination limit Bq/cm^2 ($dpm/100cm^2$)(2)	Volume contamination limit (Bq/g)(2)
Group 1: High energy gamma emitters, radium, thorium, transuranics, and mobile beta-gamma emitters (e.g., Pu, Ra, Th)	0.1 (600)	0.1
Group 2: Uranium(3) and selected beta emitters (e.g., Sr-90, U-234, U-235, U-238)	1 (6000)	1
Group 3: General beta-gamma emitters (e.g., Be-7, Pu-241)	10 (60,000)	10
Group 4: Low-energy beta-gamma emitters (e.g. H-3)	100 (600,000)	100
Group 5: Low energy beta emitters (e.g., Sr-89)	100 (600,000)	100
(1) Screening levels do not include background levels.		
(2) Assuming an average surface to mass ratio of 1:1		
(3) Natural uranium screening levels for clearance shall be lowered from Group 2 to Group 1 if decay-chain progeny are present		

Distributions of Measurements on Uncontaminated Building Materials

Table 6 provides the summary data from individual gross alpha and beta measurements of surface radioactivity for common building materials, as well as the ratios of the measured beta and alpha activity. Figures 1 and 2 show the comparisons of the surface activities across the different materials graphically. Beta values generally range between 500 and 5000 dpm/100 cm^2 and alpha activities range between 10 and 500 dpm/100 cm^2. This difference is also observed in the beta/alpha activity ratios. In the event that higher than usual background rates are measured, the data analyst may determine that net counts are more appropriate for comparison and statistical analysis. Table 7 provides the summary data from individual net alpha and beta measurements of surface radioactivity for common building materials, as well as the ratios of the measured beta and alpha activity. To avoid censoring the data, all net values, even negative values, were used to calculate the summary statistics. Figures 3 and 4 show the comparisons of the surface activities across the different materials graphically. While the scope of this paper is to report measurement results from uncontaminated building materials, Table 6 and 7 surface activities can be used to determine if field measurements on building materials are indistinguishable from background (IFB). MARSAME describes appropriate comparisons and statistical approaches to test for differences in field measurements from background. These IFB comparisons can include evaluations to determine if: 1) all field measurements are below the critical values, 2) the mean of the field measurements is below the 95% Upper Confidence Level (UCL) of the background measurements, or 3) the distribution of field measurements is statistically equivalent to the distribution of background measurements using non-parametric tests, such as the Wilcoxon Rank Sum Test.

Table 6: Summary statistics for measured total surface activities in various common construction materials.

Units of measurement are GROSS dpm/100 cm^2

Construction Material	Mean	Maximum	Standard Deviation	95% upper confidence level for mean
Wood (n=10)				
Alpha	29	93	29	47
Beta	906	1170	147	992
Beta/Alpha Ratio	31			
Painted Metal Interior (n=27)				
Alpha	54	592	134	167
Beta	1049	1413	148	1098
Beta/Alpha Ratio	19			
Painted Metal Exterior (n=33)				
Alpha	50	93	18	55
Beta	818	1269	164	867
Beta/Alpha Ratio	16			
Rusted Metal (n=11)				
Alpha	326	569	161	415
Beta	1355	1607	211	1471
Beta/Alpha Ratio	4			
Galvanized Metal (n=8)				
Alpha	65	93	19	78

Construction Material	Mean	Maximum	Standard Deviation	95% upper confidence level for mean
Beta	790	869	66	834
Beta/Alpha Ratio	12			
Bare Metal (n=25)				
Alpha	12	29	7	15
Beta	1237	1632	252	1324
Beta/Alpha Ratio	99			
Painted Concrete Poured Interior (n=25)				
Alpha	17	39	10	21
Beta	1568	2427	313	1676
Beta/Alpha Ratio	88			
Painted Concrete Poured Exterior (n=25)				
Alpha	28	63	13	32
Beta	1379	1688	189	1444
Beta/Alpha Ratio	49			
Bare Concrete Poured Interior (n=20)				
Alpha	15	107	23	38
Beta	1653	1948	167	1718
Beta/Alpha Ratio	107			
Bare Concrete Poured Exterior (n=24)				
Alpha	81	155	41	96
Beta	1686	2247	274	1782
Beta/Alpha Ratio	20			
Painted Cinderblock (n=25)				
Alpha	27	68	17	33
Beta	1938	2248	276	2033
Beta/Alpha Ratio	69			
Bare Cinderblock Exterior (n=20)				
Alpha	66	128	31	78
Beta	1774	2695	477	1986
Beta/Alpha Ratio	26			
Ceramic Brick (n=25)				
Alpha	95	179	47	111
Beta	2153	2660	458	2311
Beta/Alpha Ratio	22			
Ceiling tile (n=25)				
Alpha	23	43	10	27
Beta	1493	1854	156	1547
Beta/Alpha Ratio	63			
Floor tile (n=25)				
Alpha	9	30	7	11
Beta	1156	1460	129	1200
Beta/Alpha Ratio	126			
Porcelain (n=25)				
Alpha	59	123	25	68
Beta	2149	2621	198	2217

Construction Material	Mean	Maximum	Standard Deviation	95% upper confidence level for mean
Beta/Alpha Ratio	35			
Ceramic Tile (n=125)				
Alpha	63	166	37	77
Beta	2018	3221	334	2068
Beta/Alpha Ratio	31			
Carpet (n=9)				
Alpha	184	600	242	687
Beta	1122	1345	144	1212
Beta/Alpha Ratio	6			
Composite Laminates[1] (n=19)				
Alpha	253	1423	392	645
Beta	1193	2100	311	1315
Beta/Alpha Ratio	4			
Painted Wallboard (n=7)				
Alpha	178	601	260	1157
Beta	1020	1507	273	1221
Beta/Alpha Ratio	5			
Stucco (n=7)				
Alpha	46	53	6	51
Beta	1099	1245	120	1188
Beta/Alpha Ratio	23			
Glass (n=5)				
Alpha	13	17	3	16
Beta	940	997	58	995
Beta/Alpha Ratio	70			
Rubber (n=25)				
Alpha	17	39	9	20
Beta	1133	1770	318	1255
Beta/Alpha Ratio	66			
Roofing Composite[2] (n=10)				
Alpha	44	88	27	60
Beta	1344	1596	172	1444
Beta/Alpha Ratio	30			

[1] Composite Laminates: laminated tables, laminated counter, plastic, and linoleum

[2] Composite Roofing: Asphalt and gravel

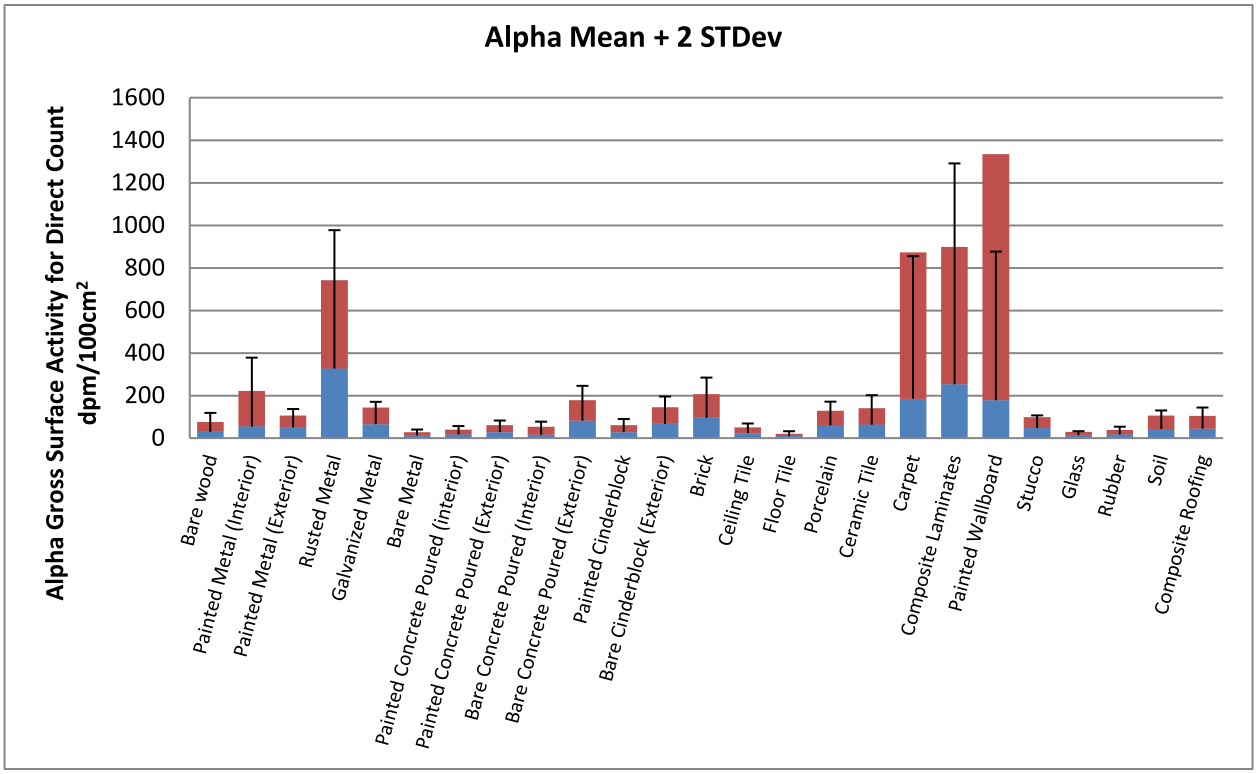

Figure 1: Measurements of gross alpha activity for various surfaces. Mean value is indicated by the blue bottom bar, 95% UCL by the orange upper bar, and mean plus two standard deviations by the whisker.

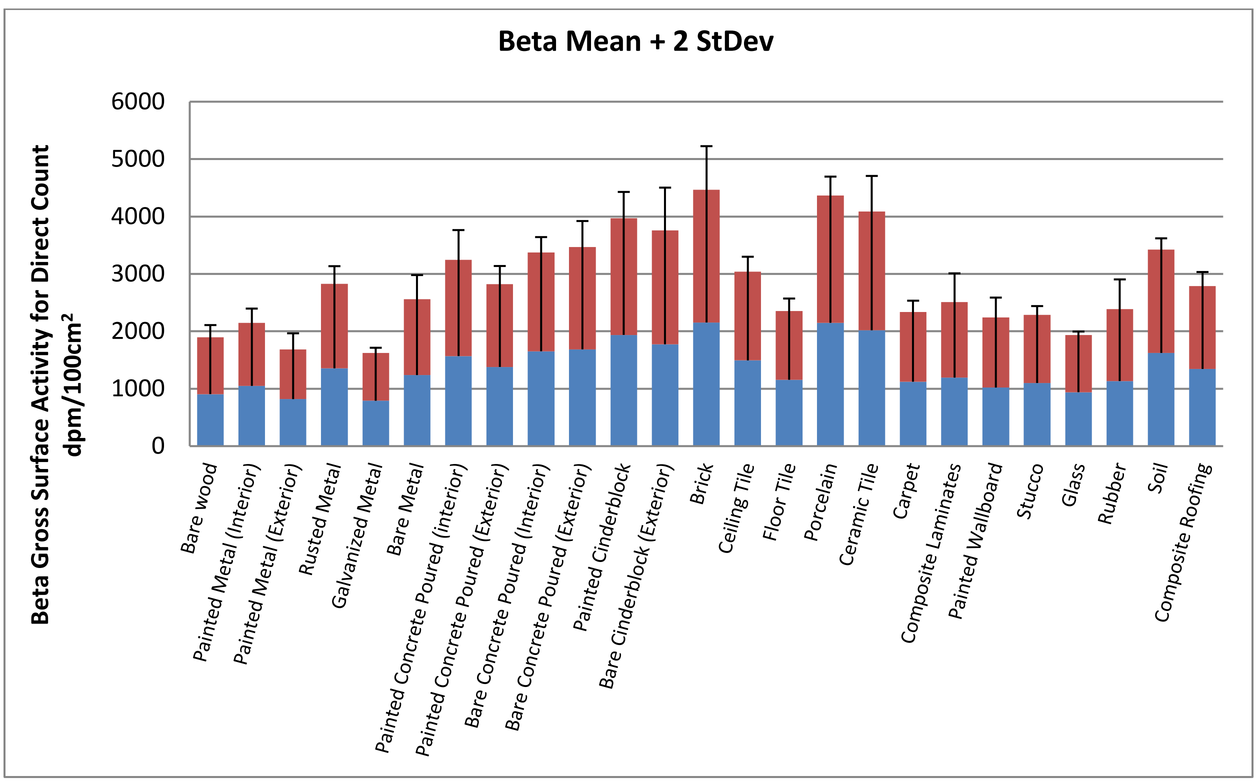

Figure 2: Measurements of gross beta activity for various surfaces. Mean value is indicated by the blue bottom bar, 95% UCL by the orange upper bar, and mean plus two standard deviations by the whisker.

Table 7: Summary statistics for measured total surface activities in various common construction materials.

Units of measurement are NET dpm/100 cm^2

Construction Material	Mean	Maximum	Standard Deviation	95% upper confidence level for mean
Wood (n=10)				
Alpha	19	80	26	34
Beta	0	0	0	0
Beta/Alpha Ratio	0			
Painted Metal Interior (n=27)				
Alpha	7	36	13	12
Beta	36	231	97	68
Beta/Alpha Ratio	4			
Painted Metal Exterior (n=32)				
Alpha	33	80	21	40
Beta	-63	245	186	77
Beta/Alpha Ratio	-2			
Rusted Metal (n=11)				
Alpha	299	551	164	389
Beta	219	469	188	322
Beta/Alpha Ratio	1			
Galvanized Metal (n=8)				
Alpha	49	80	19	62
Beta	0	0	0	0
Beta/Alpha Ratio	0			
Bare Metal (n=25)				
Alpha	-0.01	24	10	9
Beta	-11	184	142	37
Beta/Alpha Ratio	946			
Painted Concrete Poured Interior (n=25)				
Alpha	2	14	6	8
Beta	441	622	106	478
Beta/Alpha Ratio	158			
Painted Concrete Poured Exterior (n=25)				
Alpha	14	53	13	19
Beta	286	578	146	336
Beta/Alpha Ratio	19			
Bare Concrete Poured Interior (n=20)				
Alpha	5	101	24	29
Beta	324	591	130	374
Beta/Alpha Ratio	54			
Bare Concrete Poured Exterior (n=25)				
Alpha	61	135	41	75
Beta	470	767	207	650
Beta/Alpha Ratio	7			
Painted Cinderblock (n=25)				
Alpha	8	45	15	13

Construction Material	Mean	Maximum	Standard Deviation	95% upper confidence level for mean
Beta	443	675	189	608
Beta/Alpha Ratio	52			
Bare Cinderblock Exterior (n=20)				
Alpha	55	116	34	69
Beta	501	880	192	575
Beta/Alpha Ratio	8			
Ceramic Brick (n=25)				
Alpha	79	169	47	95
Beta	768	1152	249	853
Beta/Alpha Ratio	9			
Ceiling tile (n=25)				
Alpha	11	43	12	15
Beta	374	782	230	453
Beta/Alpha Ratio	33			
Floor tile (n=25)				
Alpha	-1	22	9	7
Beta	134	248	88	165
Beta/Alpha Ratio	-89			
Porcelain (n=25)				
Alpha	46	108	26	55
Beta	1057	1348	218	1132
Beta/Alpha Ratio	22			
Ceramic Tile (n=125)				
Alpha	51	156	37	57
Beta	839	2305	388	896
Beta/Alpha Ratio	16			
Carpet (n=9)				
Alpha	23	82	34	73
Beta	51	286	99	196
Beta/Alpha Ratio	2			
Composite Laminates[1] (n=19)				
Alpha	85	905	216	302
Beta	60	484	145	206
Beta/Alpha Ratio	0.7			
Painted Wallboard (n=7)				
Alpha	9	45	16	36
Beta	41	183	74	164
Beta/Alpha Ratio	4			
Stucco (n=7)				
Alpha	18	44	17	31
Beta	89	220	71	142
Beta/Alpha Ratio	4			
Glass (n=5)				
Alpha	2	13	5	14
Beta	3	17	7	18

Construction Material	Mean	Maximum	Standard Deviation	95% upper confidence level for mean
Beta/Alpha Ratio	1			
Rubber (n=25)				
Alpha	7	34	10	10
Beta	35	358	134	81
Beta/Alpha Ratio	5			
Roofing Composite[2] (n=10)				
Alpha	12	44	16	34
Beta	206	477	144	
Beta/Alpha Ratio	16			

[1] Composite Laminates: laminated tables, laminated counter, plastic, and linoleum

[2] Composite Roofing: Asphalt and gravel

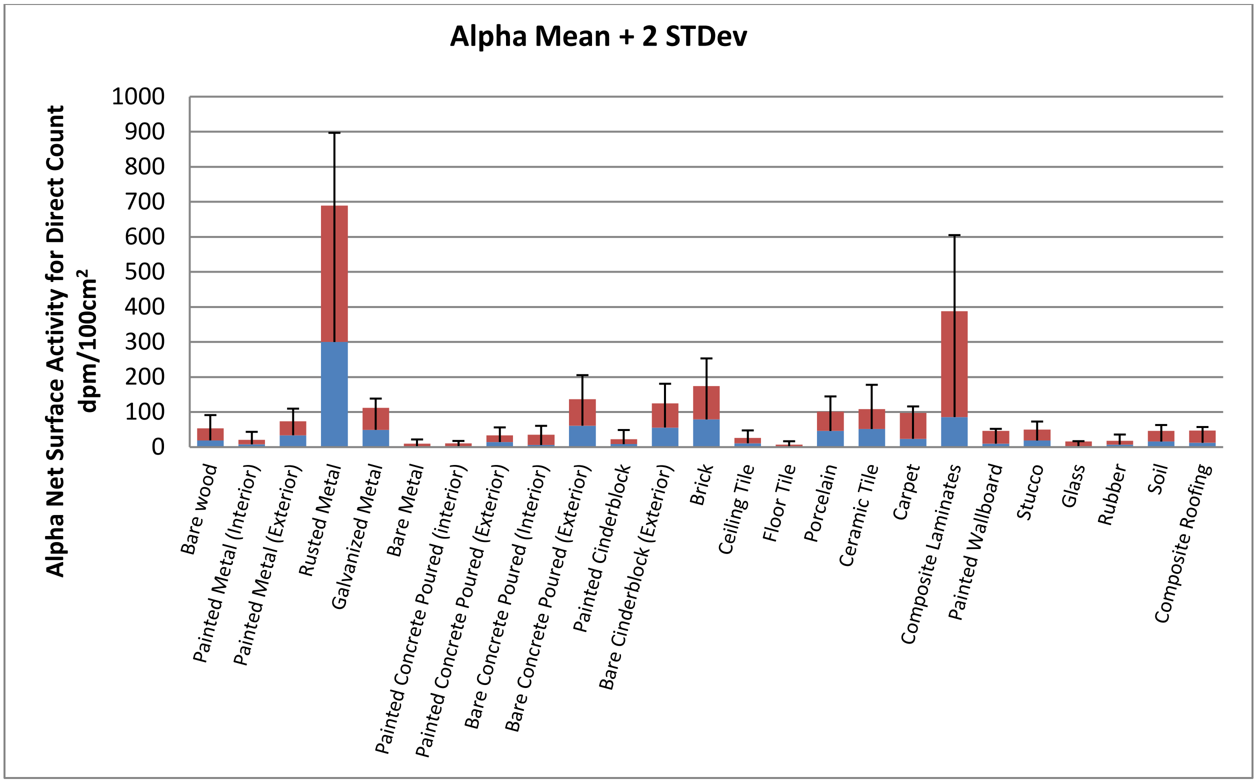

Figure 3: Measurements of net alpha activity for various surfaces. Mean value is indicated by the blue bottom bar, 95% UCL by the orange upper bar, and mean plus two standard deviations by the whisker.

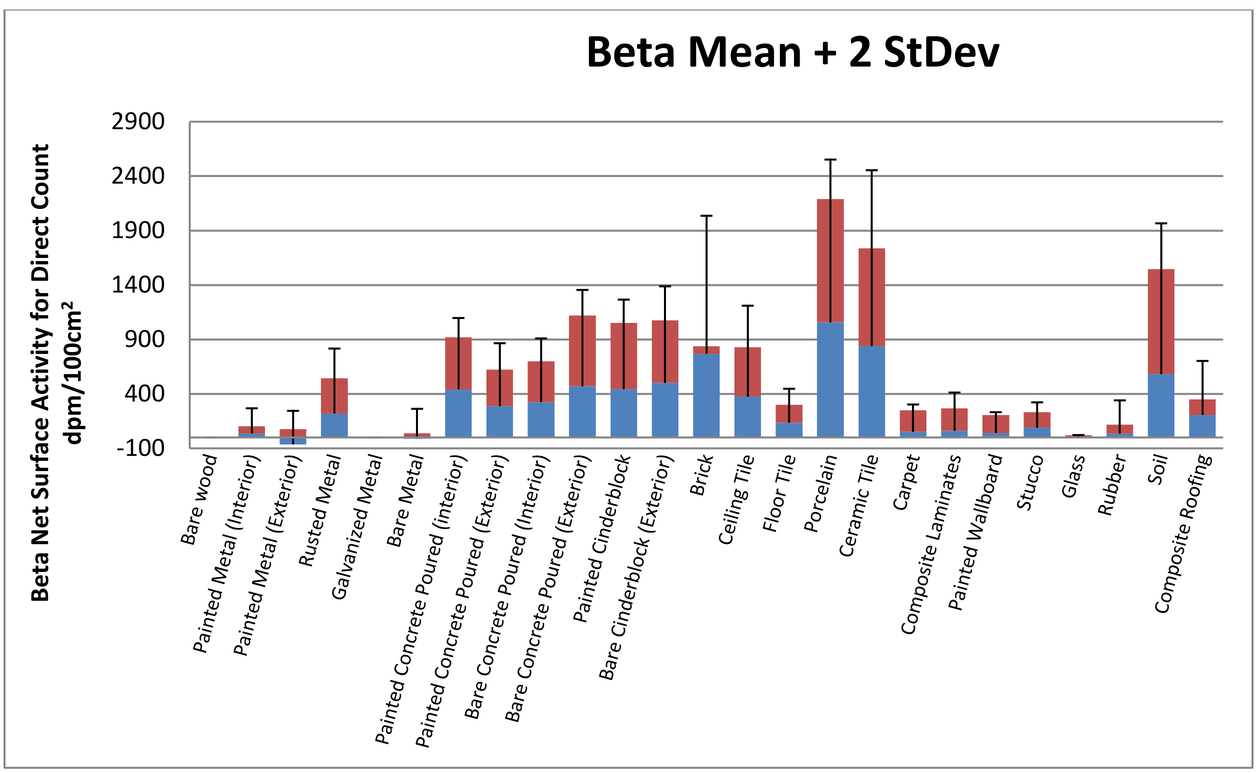

Figure 4: Measurements of net beta activity for various surfaces. Mean value is indicated by the blue bottom bar, 95% UCL by the orange upper bar, and mean plus two standard deviations by the whisker.

Conclusions

Employing the same methodology as Whicker et al., 2015; this study provides reference measurements with the Ludlum 43-93 that can then be used to statistically evaluate whether gross or net measurements on these building materials are indicative of contamination from nuclear operations in the facility, or alternatively, if the measurements reflect NORM and are indistinguishable from background.

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